SOME RECENT ADVANCES IN MOSQUITO WORK.

THOMAS J. HEADLEE, Ph. D.,
Entomologist of the N. J. Agric. Experiment Stations.

CHARLES S. BECKWITH, B. Sc.,
Assistant Entomologist of the N. J. State Experiment Station.

At the outset the writers wish to state the present status of mosquito work in New Jersey. Approximately 95,000 acres of the salt marsh has been rendered reasonably free from mosquito breeding. This has involved the cutting of about 11½ million feet of ditches 10 inches wide and thirty inches deep or their equivalent, the building of 17.2 miles of dike, the installation of 76 sluices and tide gates (representing 842 sq. ft. of cross section outlet opening), the installation of one four and one twelve inch centrifugal pump and the connection of 100 acres of marsh with a large sewage pumping plant. Approximately 50 per cent of the reasonably permanent fresh water mosquito breeding pools scattered over 315,000 acres of upland has been permanently eliminated.

During the past year 3,289,120 linear feet of narrow 10 x 30 inch trenching or its equivalent has been installed in the salt marsh, 8,200 lineal feet of dike have been built, and 30 sluices and tide gates have been constructed and placed, affording 371 sq. ft. of cross section outlet. Approximately 95,000 acres of salt marsh have been patrolled throughout the mosquito season and the mosquito breeding thereon, which drainage systems did not prevent, destroyed in so far as possible. Approximately 315,000 acres of upland have been likewise patrolled, a large amount of draining and filling completed, and as nearly as possible all residual breeding destroyed. As a direct result a very considerable measure of protection has been given to 1¾ millions of people. The cost of the whole operation has been less than $210,000, or about 12 cents per capita.

Although a certain amount of drainage is yet to be done within the areas already covered, the great centers of population, which were formerly over run with mosquitoes, are now pretty well protected; and the present outlook is that the protection will grow better from year to year through the substitution of permanent for temporary elimination.

The great problem yet remaining is to free the sea shore and rural communities of southern New Jersey from the mosquito incubus by draining the remaining acreage of salt marsh.

Until 1912 the sole official agencies at work were the boards of health and the New Jersey State Agricultural Experiment Station, and for various reasons little was accomplished by the former. Since that year the County Mosquito Extermination Commissions and the New Jersey Experiment Station have worked on the problem in close co-operation.

In 1916, under the able and effective leadership of Dr. Haven Emerson, Commissioner of Public Health of the City of Greater New York, all salt marshes lying within its borders (except those on Staten Island, which were drained some years ago), have been drained or are now in the process of being drained. Under the authority of an act of 1916 a mosquito commission was organized in Nassau County, which lies in Long Island just east of the Brooklyn and Queens Division of Greater New York, and the work of draining the salt marshes, which had already been begun on the south side by private subscription, was undertaken in a systematic manner. The amount of work involved in Greater New York and Nassau County is shown by the fact that more than 5,000,000 lineal feet of narrow trenching or its equivalent have been cut or contracted for cutting. In addition to this, a certain amount of upland control work has been done, but with its exact nature and extent the writers are not familiar.

For the purpose of unifying the mosquito control work of the three states concerned, an Inter-State Anti-Mosquito Committee was formed under the leadership of Dr. Emerson. The committee consists of representatives of Connecticut, New York and New Jersey.

Having laid this basis the writers will now turn attention to some of the striking changes that have been made in response to the practical needs of mosquito control work.

CHANGES IN SALT MARSH DRAINAGE.

In 1904 at the close of the preliminary investigations of the problem it was thought to be necessary to drain only the marsh where breeding was found in such a way as to cause the water to flow in and out with the tide and to afford the killifish ingress at all times to all parts of the salt marsh known to breed. In

fact, this continued to be the thought until 1913, when it became clear to the senior author and others that there were at least two fundamental weaknesses in the working out of this plan. The first was the assumption that the salt marsh has certain breeding areas which may be determined in the course of one or two inspections and which if drained will free the marsh from breeding. The second was the assumption that all salt marshes respond to drainage systems of the above sort.

In 1913 the senior author was led to suspect and in 1914 to prove that certain areas in the salt marshes of the upper Hackensack Valley, which had been reported as in non-breeding territory, were really at times very prolific producers of salt marsh mosquitoes. This experience has since been repeated so frequently at different points of the supposedly drained salt marsh that the writers are convinced that every undrained area of grass, cattail or reed covered salt marsh is potentially dangerous unless it is swept with great frequency by the tide; and that even such tide swept areas may, in certain seasons be covered at such infrequent intervals as to permit breeding.

In 1914 the drainage systems established in Essex and Union Counties on the original plan utterly failed to prevent the issue of an enormous brood of salt marsh mosquitoes between July 15th and 20th. The failure was directly traceable to an unusual combination of long continued, extremely high tide with a period of much rain and cloudy weather. Other parts of the coast served with the same system of ditching, in many instances in a less completed state, were adequately protected. The difference seemed to lie in the fact that the east wind banked the waters up in land-locked Newark Bay and created a condition which did not obtain along the more open parts of the coast.

Although this failure was chargeable to an unusual condition of tide and weather, it was made possible by peculiar geographical location and might any year be repeated. It was, therefore, sufficient to condemn the system and to indicate that some radical change must be made.

After carefully considering the matter it was decided that the most feasible plan was to keep the sea off the marshes by dikes, to outlet the water through sluices and tide gates, and thus create a reservoir capable of absorbing heavy rainfall

without covering the surface and initiating mosquito breeding over large areas.

Accordingly, since 1913 new drainage has been planned to open not merely the places in which breeding has been found but all parts of the marsh, which are not swept at frequent intervals by the tide. Furthermore, since 1914 the areas on which the narrow trenching with its outlets failed to afford protection, have been placed under dike, sluice and tide gates as rapidly as possible.

Some salt marsh areas in the Hackensack Valley lie so low that their drainage by gravity flow is impracticable and they have in some instances become so charged with sewage as to breed the house mosquitoes as well as the salt marsh forms. In such places low head centrifugal pumps are being installed as rapidly as possible. A twelve inch pump of this type seems to be able to protect from 800 to 1,000 acres of land.

In the course of this diking, sluicing, and pumping work the problem of taking care of the sewage has presented itself. As a rule the open sewage streams have been arranged to open into tidal creeks, with a result that the ditches and creeks have soon become choked up and the raw sewage spread over large areas of the marsh. The plan adopted has been one of diking the borders of these sewage charged ditches and creeks, thereby causing the sewage to be carried out to sea by gravity, and to outlet the waters of the marsh either through sluices or by pumps into the sewage charged streams or other available outlets. Inasmuch as the city and borough engineers have usually planned to outlet their sewers into the best tidal streams of the areas in question it has been necessary as well as to deliver the marsh water through them.

ADVANCES IN KNOWLEDGE OF MOSQUITO DISTRIBUTION.

The method of determining the flight of salt marsh mosquitoes formerly practiced consisted in securing of reports from cooperating observers relative to the time when the mosquitoes arrive, and in efforts to follow their flights along trolley and railroad lines. With the advent of the automobile as a common means of transportation tracing the flight of salt marsh mosquitoes became a simple matter. In a day's time a freshly emerged brood could be traced to its source, and the basis promptly laid for the prevention of further

trouble from that area. This method of tracing broods of salt marsh mosquitoes was first tried in 1913 and the results were so satisfactory that it has been used constantly since that time.

In making a study of this sort, the usual plan is to drive to a point where the brood has been reported. From this point, collections are made outward along lines running to the north, west, south and east until no further specimens can be taken, or until the marsh from which the mosquitoes came has been reached. This will, without doubt reveal the direction of the source of the brood, unless the mosquitoes have been out long enough to lose their connection with the marsh from which they came. When the marsh from which the brood came, has been reached, some idea of the part from which it came can be had by running a collection line along the edges and discovering the point where the mosquitoes are most abundant. In most cases the place of breeding will be found nearest this point, but in others this process will offer little clue, for a heavy growth of trees may attract sufficient numbers to give a false impression or the direction of the wind may have produced concentration at a distant point. Nevertheless the determination of density gives a point of departure and is worth while when dealing with the problem of finding the pupal skins on a large area of salt marsh.

In running these collection lines the purpose is to determine the density of the mosquito fauna. It is, therefore, necessary to organize each collection on some sort of a unit basis, and in order to eliminate the serious interference of local conditions to make all collections in as nearly similar situations, especially as relates to cover, as possible. The whole series of collections is usually made within the limits of a single day. Starting in the morning about 8:00 A. M., collections along the first line are made. At each point the collector gets out of the machine, enters the type of growth selected and using two cyanide tubes catches as many specimens as possible in a limited period—say 15 minutes. He then reckons his catch in terms of so many specimens of the species concerned per minute. The distance between stations depends upon the area to be covered. When dealing with a small area the intervals are short, say, anywhere from ¼ to 1 mile, but when dealing with an issue that covers a large area the distances range from 2 to 5 miles.

In 1913 the success in tracing the salt marsh species lead to an attempt to trace the house mosquito which exhibited marked concentration in certain areas within which and in the vicinity of which no serious breeding of the species could be found. Daylight collections promptly proved inadequate because the house species would not readily attack the collector. Resort was then had to evening collections, but the variations in time required for one collector to cover the whole area seemed to introduce a variable fatal to the result. To meet this difficulty a number of collectors were employed along two lines of collection running through the mosquito zone at right angles to each other. Enough men were employed that the entire collection could be secured within the limits of 1½ hours. By this means the collections were found to bear an understandable relation to each other, and by following the directions of increasing density the source of breeding has been found. In this way a zone of house mosquitoes originating in a sewage charged salt marsh has been found which extended a distance of 2½ miles from the place of origin.

The fact that nearly all species were taken in these evening collections led the senior author to wonder whether the process might not be used to determine the density of the mosquito fauna throughout the protected area and thereby check up the efficiency of the control work and point out the places where greater effort was needed.

In 1914 he had an opportunity to try out the matter in Passaic County with the efficient assistance of Mr. David Young. He found that not only did the method seem to show up the efficiency of the control work, but served to demonstrate the inefficiencies in time to permit their correction before the householder was seriously troubled. The study seemed to show that there existed a mosquito fauna of such an attenuated character that the householder did not realize its existence and that variation in it could be determined in time to head off a really dangerous increase in number.

In 1915 the evening collection became a part of the regular mosquito control work in Essex, Passaic and Union Counties and in 1916 it was employed in Bergen, Essex, Passaic, and Union and utilized to some extent in Hudson, Middlesex, Monmouth, and Atlantic Counties. It has enabled these counties to detect promptly invasions from extra-territorial limits as well as incipi-

ent outbreaks within their boundaries. In 1916 it served to demonstrate that the dominant species in Bergen, Essex, Middlesex, Passaic and Union was the fresh-water swamp mosquito (*Aedes sylvestris* Theob.) and to show that the next problem consisted in the elimination of the breeding places of that species.

In 1914 Mr. Harold I. Eaton, Chief Inspector of the Atlantic County Commission, undertook the determination of the important factors governing the flight of the white marked salt marsh species (*A. sollicitans Wlk.*), for the purpose of determining where the limited amount of money available for the use of his commission could be spent with the prospect of affording the people of the county the largest measure of protection. Atlantic County has 50,000 acres of salt marsh and beyond its borders both to the north and the south lie many thousands of acres of undrained marsh. He found that this species took flight on winds of low velocity (10 miles an hour or less), high relative humidity, and high temperature. Under other conditions than these, migration proceeds with extreme slowness and covers only short distances. The studies of the writers before and after Mr. Eaton's tests simply serve to confirm and extend the results as stated.

In 1916, Dr. F. E. Chidester, working at the time under the senior author's direction, determined that, during the mosquito season, the principal factor in the time and geographical distribution of the brown salt marsh mosquito (*Aedes contator* Coq.) and the white marked salt marsh mosquito (*Aedes sollicitans* Wlk.) is the degree of salinity of the water to which they are subjected. He found sea-water of salinity 6 to 8 per cent. to be favorable to the former and injurious to the latter, while a salinity of 10 to 15 per cent. was favorable to the latter and injurious to the former.

This discovery fitted well the observed distribution of the two species and seemed to offer an adequate explanation. Be that as it may, the brown salt marsh species is dominant in the spring and early summer throughout the area at a time when the water has been greatly diluted by melting snow and spring rains, and remains so throughout the season along the upper courses of the rivers where the salinity never rises much above the favorable per cent. The white marked salt marsh

species is dominant from early mid-summer on or during the period when the salinity rises to the degree favorable to it.

In the beginning of a study of this sort the student may be confused by his findings, for he may discover the larvæ of both species in the same pool with salinity either high or low. He will soon find, however, that larvæ under these conditions are all well grown or that the extremely small larvæ are of the species favored by the salinity. This mix-up of large larvæ of the two species is due when the salinity is extreme in either direction, in the writers opinion, to larval distribution by high tides.

SOME UNSOLVED PROBLEMS.

Many problems of mosquito work which are important from the standpoint of the practical work of control are yet without solution.

Ditching systems on the salt marsh are rapidly multiplying and some machinery especially adapted to the work of cleaning and repairing them should be devised.

Until the late summer of 1915 and the season of 1916 the fresh water swamp mosquito had formed, except in the vicinity of great swamps, a minor portion of the problem of control. The fact that since that time it has been the dominant form over a large part of the protected area indicates clearly that a further study of its life economy must be undertaken.

Collections of mosquitoes on the wings have failed to reveal the flight habits of *Anopheles quadrimaculatus Say*. It is rarely taken in collections except very near its place of breeding.

The oils used for larvicides need to be standardized and a really practicable larvicide soluble or at least miscible with water should be found.

A practicable way to reduce the mosquito fauna, which survives the faithful practice of the present methods, should be discovered, for the failure of the mosquito fighting machine in any particular way, during trying weather, all too promptly increases the ever present minimum to a troublesome number.